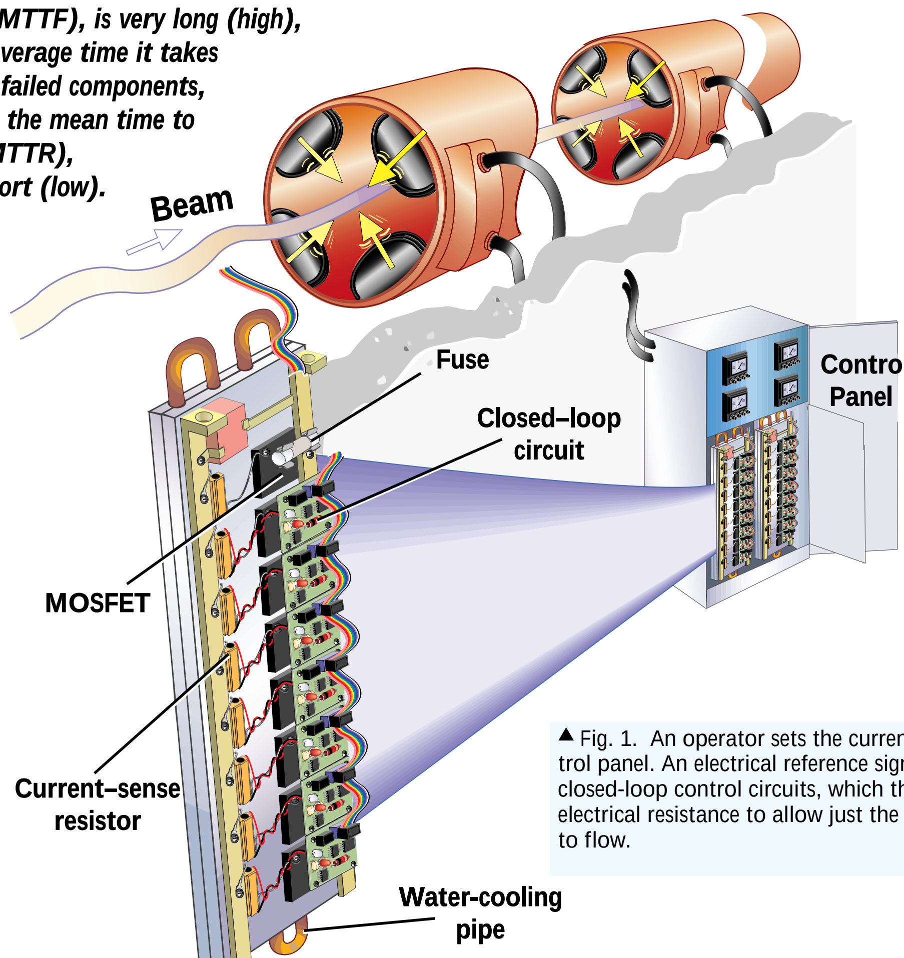
LANSCE DIVISION TECHNOLOGY REVIEW

Novel MOSFET Shunt Design that Provides High-Precision Current Sharing

Metal-Oxide Semiconductor-Field-Effect Transistor (MOSFET) circuit components are used routinely in industrial applications to control, for example, electric trains, induction furnaces, high-power radio transmitters, and other industrial equipment. MOSFETs can serve as shunts, which are electronic variable resistors used to regulate current in a power supply. Electric currents, hundreds to thousands of amperes, can be controlled using multiple MOSFET circuit components in parallel. Ensuring that currents are shared equally among multiple MOSFETs requires advanced, precise technology. We have developed a novel closed-loop circuit design that senses and adjusts current so that it is shared equally between parallel MOSFETs. Equipment that employs these components is used in LANSCE accelerator operations and run continuously for months at a time. The mechanical design and self-diagnostics of the closed-loop system have been engineered so that the average time it takes for components to fail, known as the mean time between failures (MTTF), is very long (high), and the average time it takes to repair failed components, known as the mean time to repair (MTTR), is very short (low).

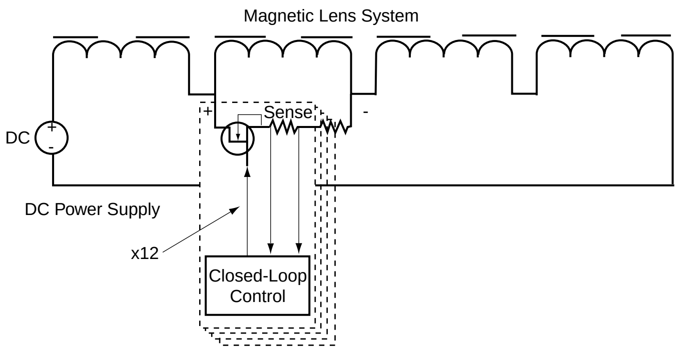
Power-Supply-Regulator Passbanks and the Proton Radiography Shunts

A number of magnets in the LANSCE beam line require power supplies that provide a constant current with regulated stability of up to ten parts per million (0.001%) to the magnets. Once accelerator operators and physicists set a specific current in a magnet, the power supply must maintain current within a tolerance of 0.001%. Devices with this strict performance specification use a passbank or electronic load resistor to provide the required precise current regulation. The passbank consists of many transistors or Metal-Oxide Semiconductor-Field-Effect Transistors (MOSFETs) connected in parallel. The challenge of using multiple circuit components is to have them share current equally. Currents on the order of hundreds or thousands of amperes need to share current equally because each individual MOSFET cannot carry the total current by itself. One way to ensure that current is shared equally is to use semiconductor devices with performance

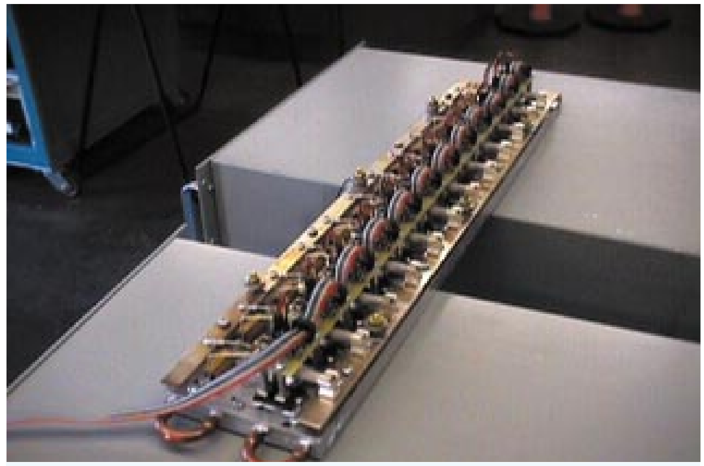


▲ Fig. 1. An operator sets the current required on the control panel. An electrical reference signal is sent to each of the closed-loop control circuits, which then adjust the MOSFETs electrical resistance to allow just the right amount of current to flow.

Illustration by Garth Tietjen



▲ Fig. 2. Schematic diagram of the placement of the MOSFET shunt in parallel with the quadrupole magnet, which is connected in series.



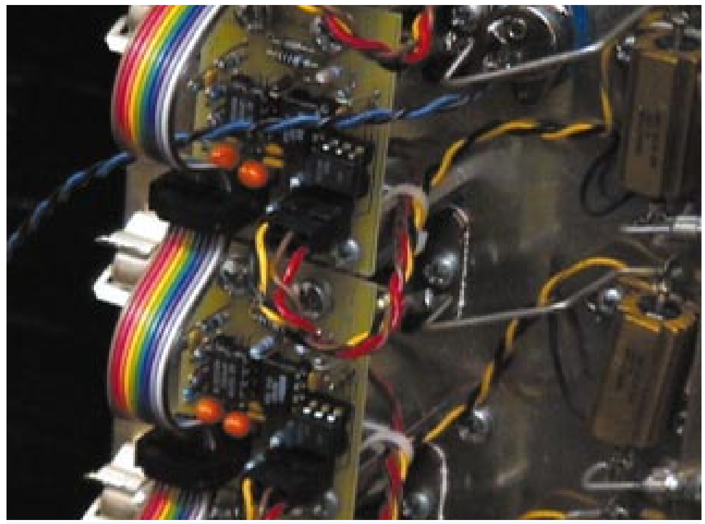
▲ Fig. 3. MOSFET passbank with closed-loop current-sharing circuitry. The MOSFET components are mounted on a water-cooled aluminum rail. The modular design and ribbon cable allow an arbitrary number of components to be wired in parallel to meet a variety of current-handing requirements.

characteristics that are nearly identical. However, this approach is very expensive because it requires a large inventory of semiconductor devices.

The LANSCE-6 Magnet Power Supply Team took an alternative approach to facilitate equal current sharing among the MOSFETs by designing each component with separate closed-loop control circuitry (Figs. 1 and 2). This paradigm allowed us to use more generic parts because a feedback loop on each device guarantees even current distribution. The design includes features that allow easy maintenance, testing, and repair. The entire assembly is modular in design so that a single inoperative MOSFET can be replaced without the need to disassemble nearby components (Figs. 3 and 4). Testing can be done safely without any disassembly or removal of the passbank from its mounting.

Brookhaven E933 Magnet Shunt System

The MOSFET passbank design was adapted for use as a remote-control dual-channel current shunt for the proton radiography (PRAD) experiment at Brookhaven National Laboratory. Because the shunt operated about 100 V above ground, for safety reasons the remote-control circuitry is electrically isolated from the shunt assembly. The shunts can handle 100 A per channel. The entire system was built into a single 19-in rack and was shipped to Brookhaven National Laboratory for installation, adjustment, and testing. The shunts were used successfully by the LANL PRAD collaboration during the August 1999 E-933 experimental run.



▲ Fig. 4. MOSFET passbank close-up. Note that each feedback circuit on the printed circuit board is mounted directly above the MOSFET components. The tinned wire loop (right center) is a test point for a non-contacting clamp meter.

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